Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Maritimes Region | Science Response 2016/035

REVIEW OF SCOTIAN SHELF SNOW CRAB ASSESSMENT RESULTS FOR 2015

Context

Advice on the status of the Scotian Shelf Snow Crab stock is requested annually by Fisheries and Oceans Canada (DFO) Fisheries and Aquaculture Management Branch, and Industry, to help determine a Total Allowable Catch (TAC) for 2016. Science advice for the management of the Snow Crab stock was last provided at a fully peer-reviewed stock assessment at an inclusive Regional Advisory Process (RAP) meeting in February 2015 (Cook et al. 2015). The current report provides information on the post fishery stock status for 2015, and advice for management of the 2016 fishery.

This Science Response Report results from the Science Response Process of March 3, 2016, on the Stock Status Update of Eastern Scotian Shelf and Northwest Atlantic Fisheries Organization (NAFO) Fishing Area 4X Snow Crab.

Background

Description of the Fishery

The Snow Crab fishery in eastern Canada began in 1960 with incidental by-catches by groundfish draggers near Gaspe, Quebec. Its development was slow until the 1980s, when it began expanding rapidly to become one of the largest fisheries in Canada in terms of landings and landed value. On the Scotian Shelf, the fishery has existed since the early 1970s. The fishery was initially based on effort controls (season, license, trap limits) from 1982 to 1993 with harvesting during June – November of hard-shelled males larger than 95 mm carapace width (CW). Additional management measures were introduced from 1994 to 1999: Individual boat quotas (IBQs), TACs, 100% dockside monitoring, mandatory logbooks, and at-sea monitoring by certified observers. In 2005, many Crab Fishing Areas (CFAs) and subareas were merged with the resulting divisions being N-ENS (North-Eastern Nova Scotia, formerly CFAs 20-22), S-ENS (South-Eastern Nova Scotia, CFAs 23, 24), and 4X (Figure 1).

Canada

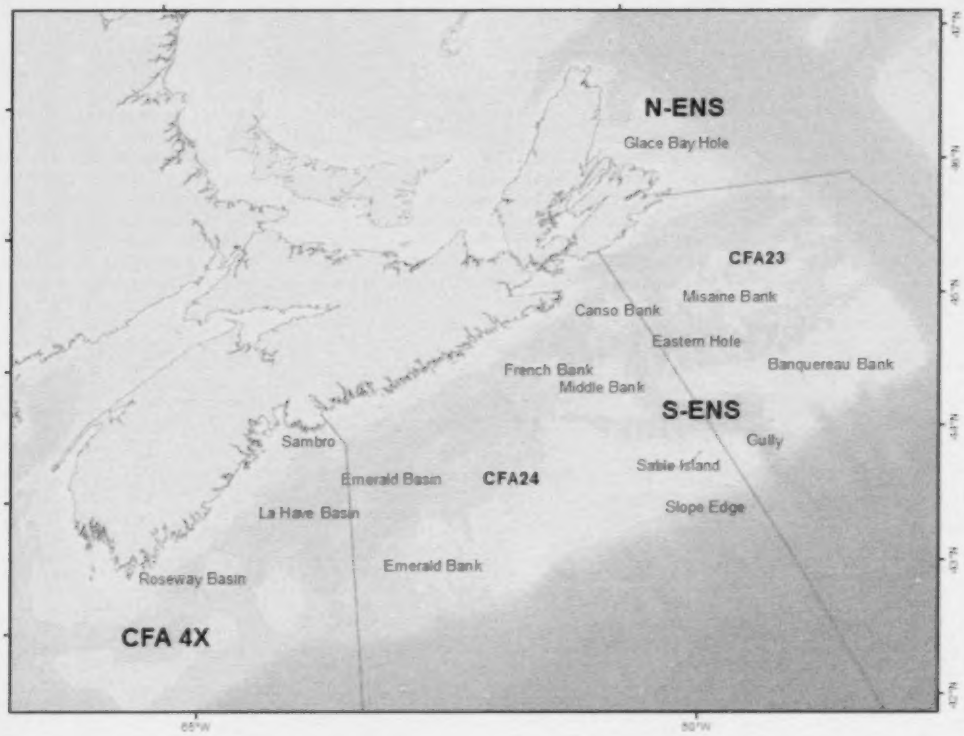

Figure 1. Map of the Scotian Shelf and Snow Crab Fishing Areas (CFAs).

Effort

In 2015, the fishing effort in S-ENS, was spatially distributed in a similar manner to 2014 (Figure 2), with a shift away from inshore fishing grounds in both CFAs 23 and 24. Much of the fishing effort continued to be focused on the holes found between Misaine and Banquereau Banks. There was a complete absence of effort in the western portion (along the "Eastern Shore") of CFA 24. Fishing patterns were affected by an overlap with spring fishing activities for shrimp, as the Snow Crab fleet has limited access to some of the most productive Snow Crab fishing zones throughout the spring months, due to area closures ("shrimp boxes"). Temporal trends in effort are presented in Figure 3.

In N-ENS, the fishing effort was focused on the trench of deep water located along the north-eastern coast of Cape Breton and in the Glace Bay Hole.

In 4X, the fishing effort was similar to the previous season. Fishing effort was concentrated around Sambro and Roseway Basin.

The spring season (2008 - present) was adopted to reduce fishing intensity in the summer season and to encourage fishing during the earlier period when newly molted crab are too weak and soft to easily enter into traps. Since 2010, the majority of landings (60%) from N- and S-ENS were caught during the spring season. Spring landings in 2015 decreased in both areas, particularly in N-ENS (21%), due to spring ice conditions. The capture of soft-shelled crab (<68 on durometer, a hardness gauge) represented less than 5% of catches in all commercial areas in 2015.

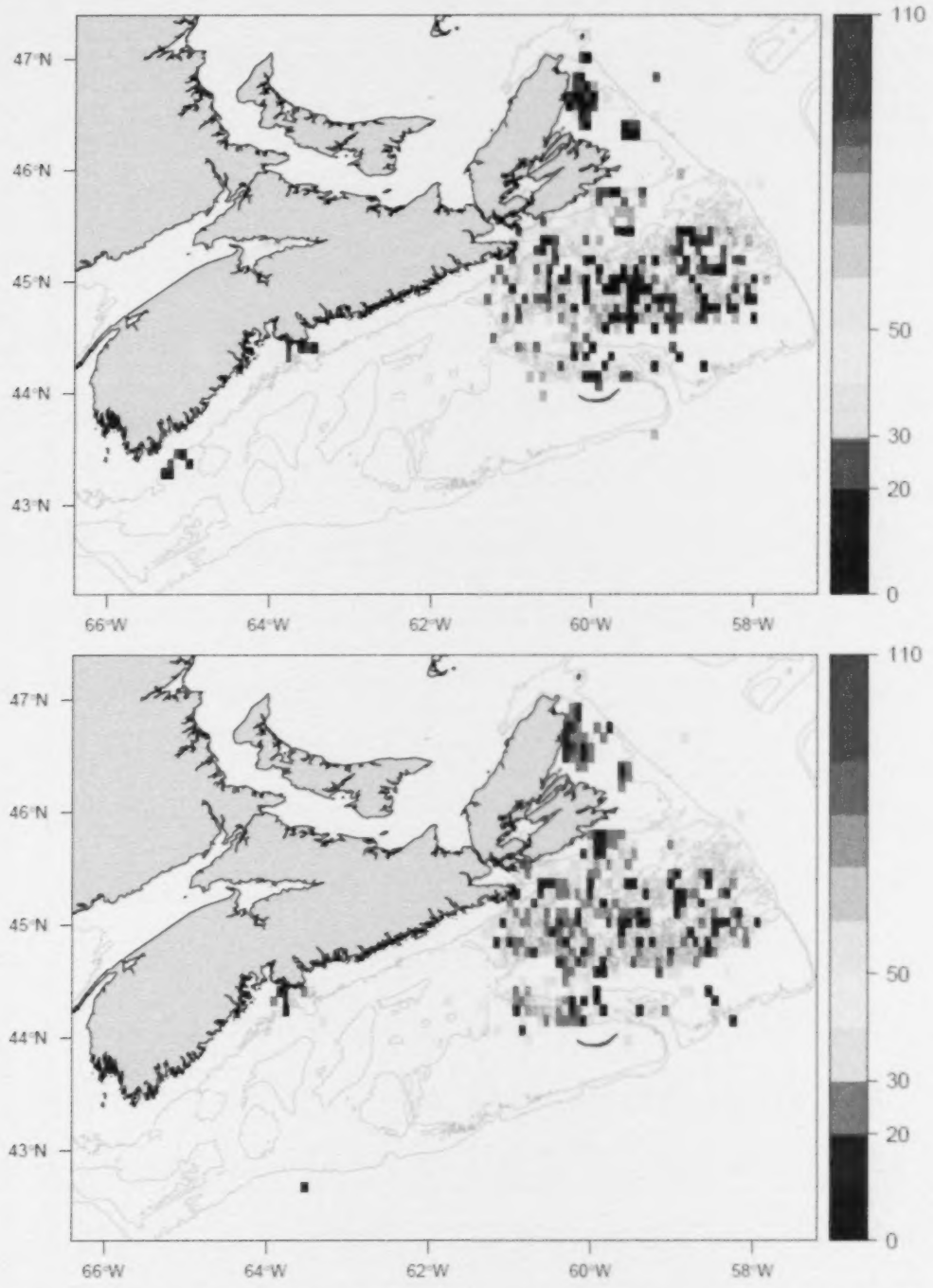

Figure 2. The spatial distribution of fishing effort (traps hauled) from fisheries logbook data for 2014 (top) and 2015 (bottom). For 4X, year refers to the starting year.

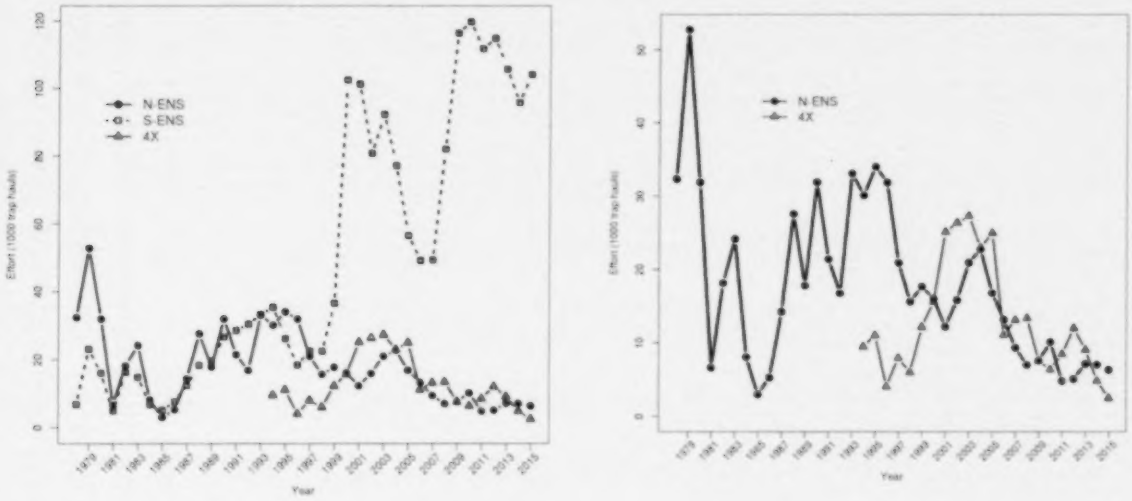

Figure 3. Temporal variations in fishing effort for Snow Crab on the Scotian Shelf, expressed as the number of trap hauls per 1 minute grid. Year in 4X refers to the year at the end of the fishing season

Landings

The Scotian Shelf Snow Crab fishery lands only males with CW greater than or equal to 95 mm. There is also a concerted effort to avoid areas of newly moulted (soft shelled) crab and to discard immature males. Total landings increased to record levels of approximately 10,000 t each year in the early 2000s and have surpassed these previous highs since 2009 (Figure 4). Landings in 2015 for N-ENS and S-ENS were 619 t and 11,292 t, respectively, which represent a 20% drop in landings for N-ENS; however, this closely follows the TACs for each region (Figure 4). As of February 25, 2016, landings in 4X for the 2014/2015 season were 120 t. This represents a 50% increase over the 2014/2015 season; however, the TAC in this area was increased by 85%. Total allowable catches in 2015 were 624 t, 11,311 t, and 150 t for N-ENS, S-ENS and 4X, respectively (Table 1).

In S-ENS, the spatial distribution of landings in 2015 (Figure 5) were similar to 2014 with a few exceptions; a reduction inshore, northeast of Sable Island (in CFA 24) and northwest of Banquereau Bank (CFA 23). In N-ENS in 2015, landings were focused on the trench of deep water located on the north-eastern coast of Cape Brenton and the Glace Bay Hole (Figure 5). There was little change in the spatial distribution of landings in 4X, with the majority of landings occurring proximal to the CFA 24 line.

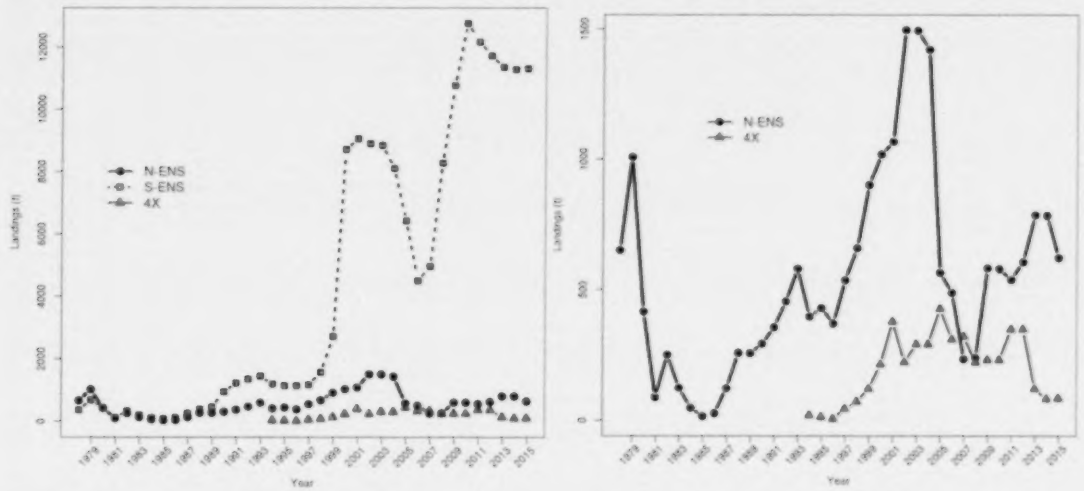

Figure 4. Temporal variations in the landings of Snow Crab on the Scotian Shelf (t). Note the sharp increase in landings associated with dramatic increases to total allowable catches (TACs) and a doubling of fishing effort in the year 2001. The landings follow the TACs with little deviation (Table 1). Year in 4X refers to the year at the start of the fishing season.

Table 1. Summary of Snow Crab fisheries activity of N-ENS (top), S-ENS (middle), and 4X (bottom). Landings are measured in tonnes, Catch per Unit Effort (CPUE) is measured as kg/trap hauled, while effort is measured per 1000 trap hauls. Note that 2015/2016 4X season data is current to February 25, 2016, as season is still ongoing. (-- = effort not available until close of fishing season.)

N-ENS					
Year	**Licenses**	**TAC**	**Landings**	**CPUE**	**Effort**
2010	78	576	576	55	10.50
2011	78	534	536	110	4.80
2012	78	603	603	117	5.10
2013	78	783	783	106	7.40
2014	78	783	778	104	7.40
2015	78	623	619	103	6.00
S-ENS					
Year	**Licenses**	**TAC**	**Landings**	**CPUE**	**Effort**
2010	116	13,200	13,150	103	128.30
2011	116	12,120	12,135	106	118.80
2012	116	11,707	11,733	98	120.00
2013	116	11,311	11,309	104	108.70
2014	116	11,311	11,300	112	100.20
2015	116	11,311	11,292	106	106.23
4X					
Year	**Licenses**	**TAC**	**Landings**	**CPUE**	**Effort**
2009/10	9	230	229	36	6.4
2010/11	9	346	345	38	9.0
2011/12	9	346	344	29	11.0
2012/13	9	263	118	13	9.6
2013/14	9	80	79	15	5.1
2014/15	9	80	82	36	2.4
2015/16*	9	150	120	34	--

*current to February 25, 2016

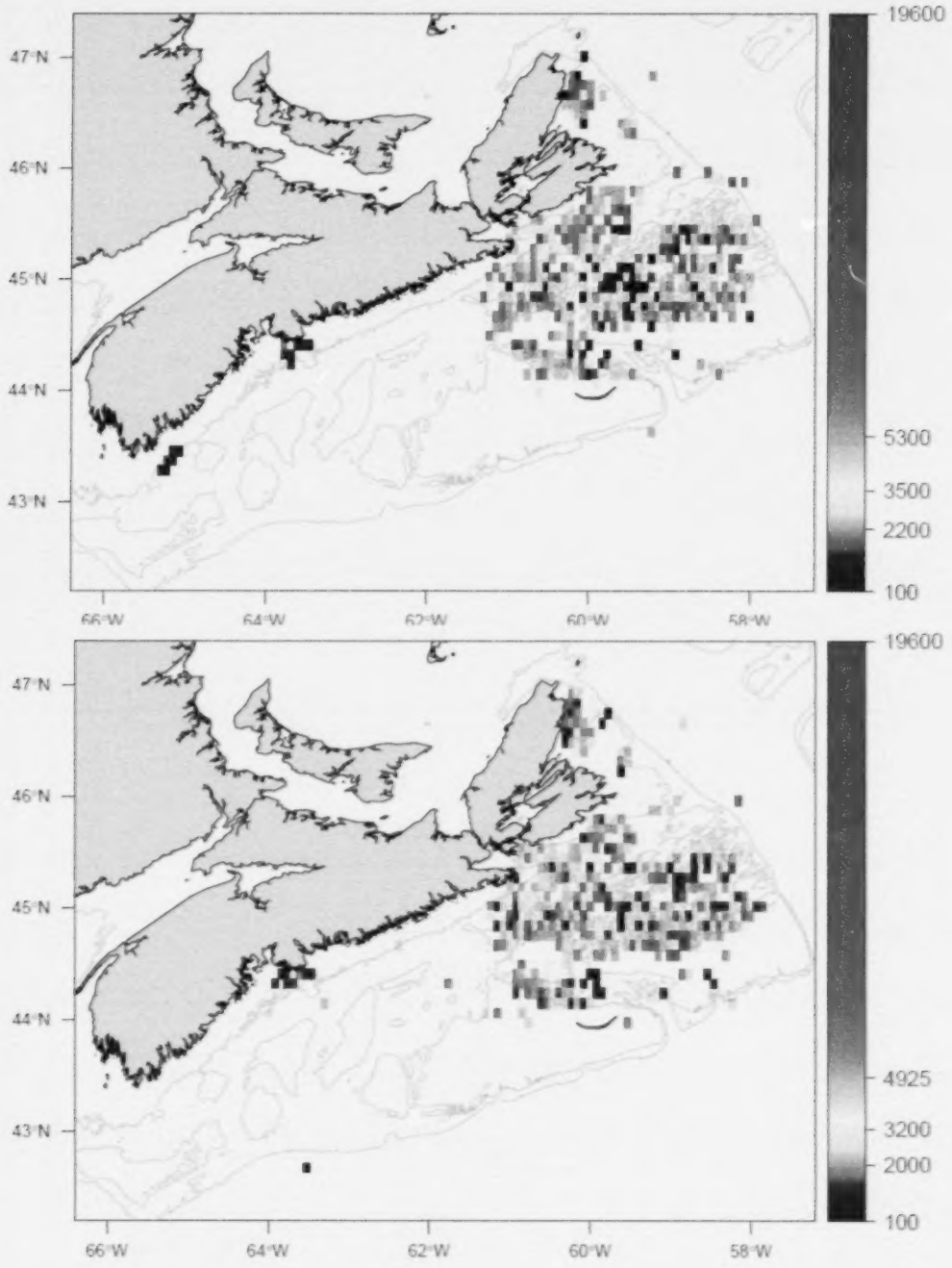

Figure 5. The spatial distribution of Snow Crab landings (kg/5 minute grid) from fisheries logbook data for 2014 (top) and 2015 (bottom). Note the decrease in landings inshore in S-ENS compared to 2014. For 4X, year refers to the starting year.

Catch Rates

Non-standardized catch rates in 2015 (Figure 6) were 103 kg/trap haul in N-ENS, 106 kg/trap haul in S-ENS, and 34 kg/trap haul in 4X in 2015/2016, which compared to the previous year represents decreases of 4%, 6%, and 5% in N-ENS, S-ENS, and 4X, respectively (Table 1, Figures 6-7). The spatial distribution of catch rates was similar to 2014, with the exception of decreases inshore, northeast of Sable Island, and northwest of Banquereau Bank in S-ENS (Figure 7).

All results for 2015 for 4X are preliminary as the season is ongoing until the end of March.

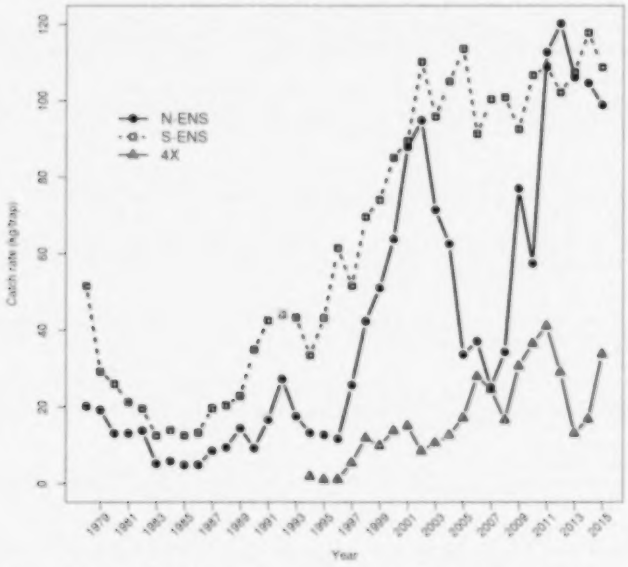

Figure 6. Temporal variations in catch rates of Snow Crab on the Scotian Shelf, expressed as kg per trap haul. These catch rates are not corrected for various factors such as trap design and size, soak time, bait, etc. For 4X, year refers to the starting year.

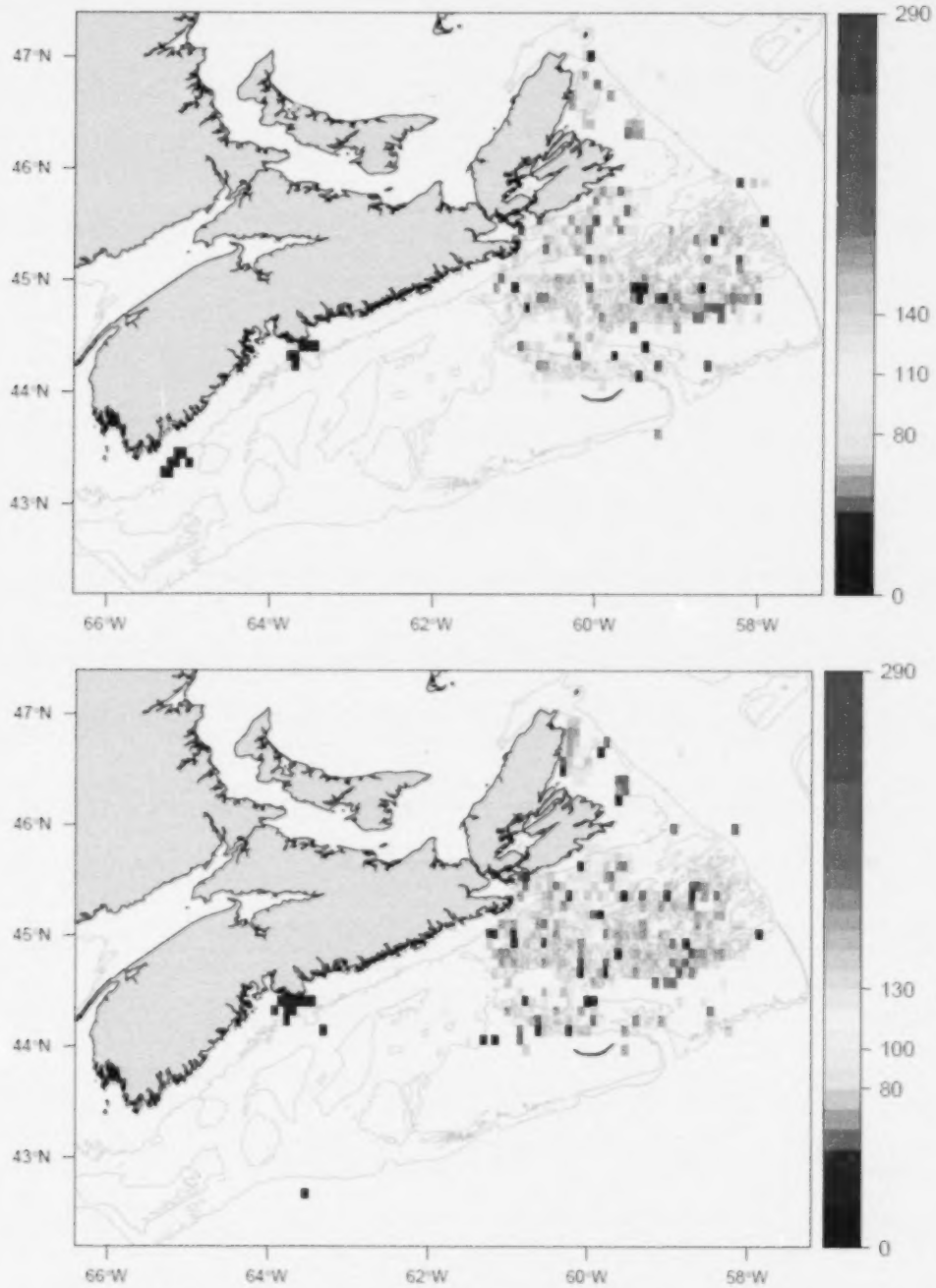

Figure 7. The spatial distribution of Snow Crab catch rates (kg/trap haul) from fisheries logbook data for 2014 (top) and 2015 (bottom). Note the decrease in catch rates inshore in S-ENS and in the eastern portion of the Eastern Holes. For 4X, year refers to the starting year.

Analysis and Response

A reference points-based Precautionary Approach (PA) has been implemented in this fishery. The Limit Reference Point (LRP) is 25% of carrying capacity and the Upper Stock Reference (USR) is 50% of carrying capacity. The target removal reference is 20% of the fishable biomass[1] in each area and the Removal Reference is not to exceed FMSY[2]. Various secondary population and ecosystem indicators are taken into consideration for management decisions.

Harvest Control Rules (HCR) have been developed that link the biomass reference points to the exploitation reference points. In the Cautious and Healthy zones, actual target harvest rates are shaped by a suite of secondary indicators that provide more complete information on the entire stock's health. The secondary indicators are used to inform management decision under the HCR linking the stock references to harvest strategies. Secondary indicators include expected recruitment, spawning stock biomass, size and age structure of various stock components, sex ratios, environmental variables, fishery performance, and others. If a stock is determined to be in the Critical Zone, all fishing activities cease, in an effort to allow the stock to rebuild.

The operational reference points associated with the 4VWX Snow Crab fishery are as follows:

- **Lower Stock Reference (LSR)**: 25% of carrying capacity
- **Upper Stock Reference (USR)**: 50% of carrying capacity
- **Removal Reference (RR)**: not to exceed FMSY
- **Target Removal Reference (TRR)**: 20% of the fishable biomass (F=0.22). Secondary, contextual indicators are used to alter harvest rates between 10 and 30% of fishable biomass (FB)(F=0.11 to F=0.36)

The Harvest Control Rules are, therefore, as follows:

- FB > USR: target exploitation rate of 10% - 30% be utilized, based upon contextual information provided by secondary indicators
- LSR < FB < USR: target exploitation rate of 0% - 20%, based upon contextual information provided by secondary indicators
- FB < LSR: fishery closure until recovery (at a minimum, until FB > LSR)

Ecosystem Considerations

Temperature

Average bottom temperatures recorded during the Snow Crab survey in 2015 were lower in all areas in comparison to 2014 (Figure 8). The Snow Crab survey more heavily surveys "core areas" of Snow Crab habitat, and does not represent the patterns on the Eastern Scotian Shelf in general. Scotian Shelf temperatures outside the "core areas" of Snow Crab habitat were warmer in 2015, potentially limiting the geographic extent of Snow Crab populations (Figure 9). It is anticipated that warmer temperatures outside primary Snow Crab habitat may affect future fishable biomass. Warmer temperatures would limit the available habitat for female and immature male crab more than the current fishable biomass. Following the extreme warm water

[1] The segment of the Snow Crab biomass that is male, mature, larger than 95 mm CW and hard-shelled (with a durometer measure of 68 or greater)
[2] F is the fishing mortality of the legal sized mature male population and MSY is the theoretical Maximum Sustainable Yield

event in 2012, bottom temperatures have decreased in 4X during the past three years; however, they still remain at the long-term mean for the area. In S-ENS, and N-ENS temperatures decreased close to the long-term mean for the areas.

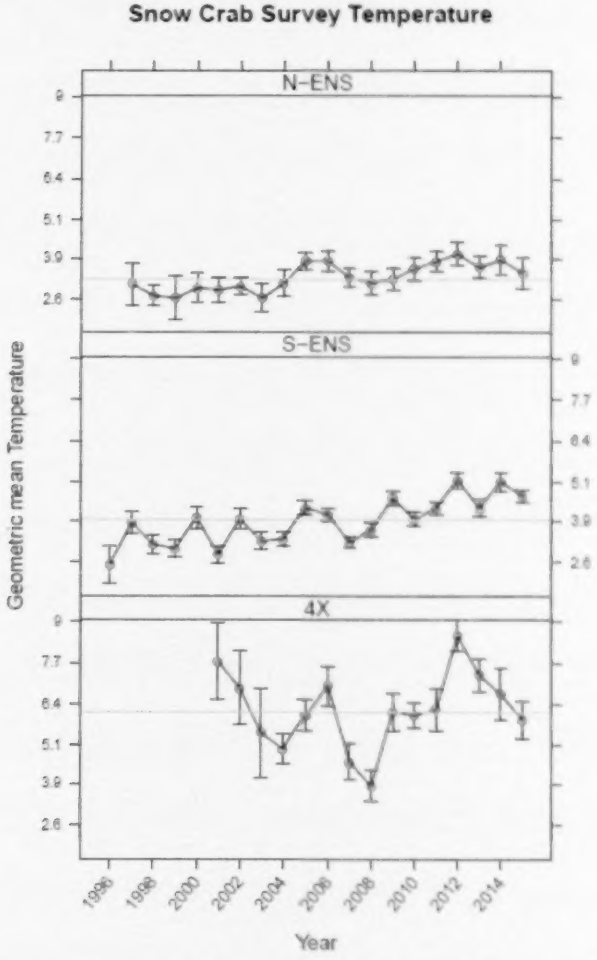

Figure 8. Annual variations in bottom temperature observed during the Snow Crab Survey. The horizontal line indicates the long-term median temperature within each sub-area. Error bars are 1 standard deviation from the mean.

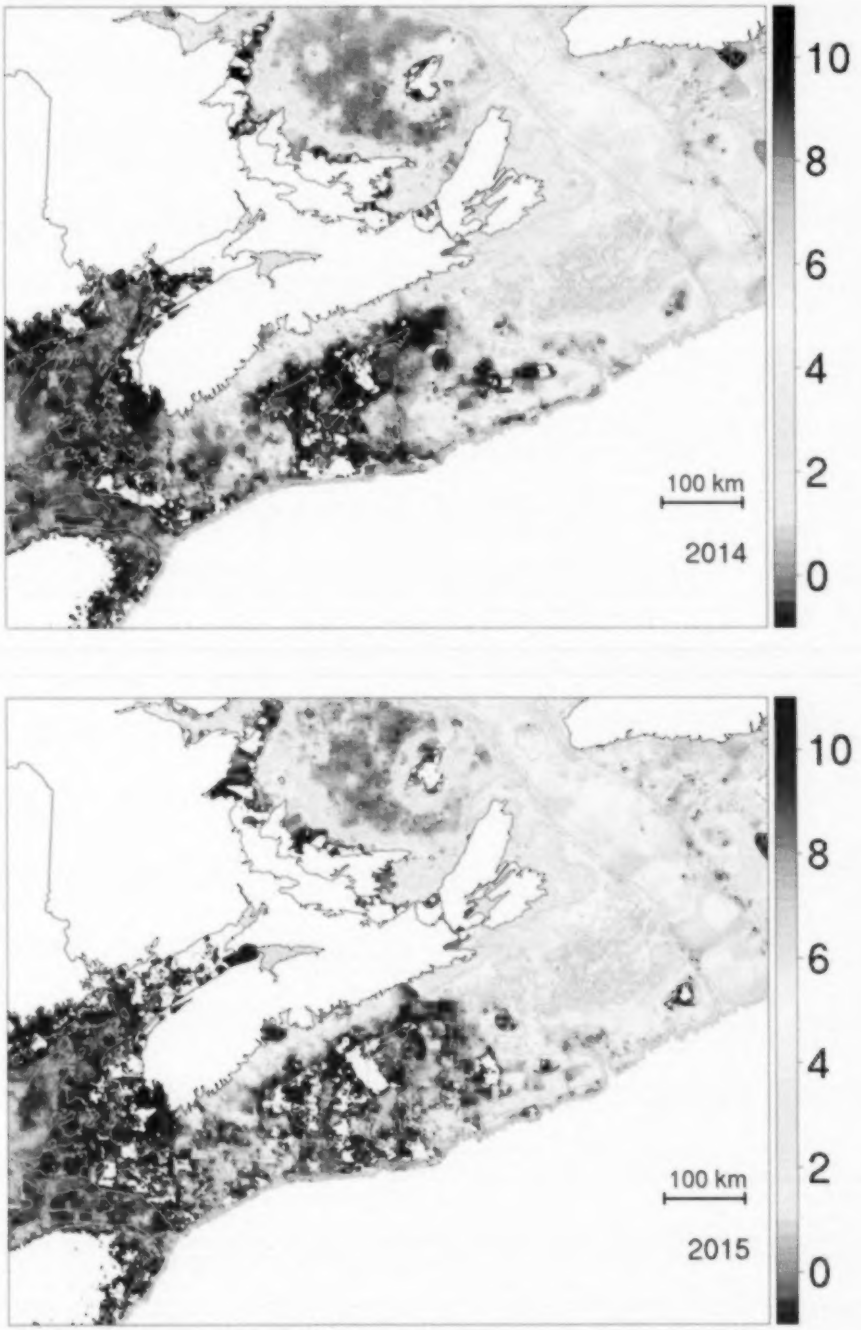

Figure 9. Interpolated mean annual bottom temperature on the Scotian Shelf for selected year. These interpolations use all available water temperature data collected in the area including Groundfish Surveys, Snow Crab surveys, and AZMP monitoring stations.

Resource Limitation, Predation, and Competition

Predation

The capacity of predatory groundfish to opportunistically feed upon snow crab, in combination with their numerical dominance prior to the 1990s, suggests they may have been an important regulating factor controlling the recruitment of snow crab. The decline of predatory groundfish in the post 1990 period and resultant reduction in predation upon immature and soft shell crab is thought to be a contributing factor to the increase of Snow Crab in the SSE. Based on stomach sampling, Atlantic Halibut, Atlantic Wolfish, and skate species appear to be the predominant predators of Snow Crab, though it does not appear to represent more than 2.2% of their diet on the Scotian Shelf. Of these species, Halibut and Cod biomass have been increasing in the Snow Crab survey. Halibut biomass has increased since 2012, except in N-ENS where it decreased in 2015; however, the biomass remains above the long term mean (Figure 10). Cod biomass has been variable, but has increased in N-ENS for the past 4 years, and has remained above the 20-year mean in S-ENS for the past 7 years. Thorny skate biomass has increased in S-ENS for the past three years and remains above the long-term mean.

Seals are considered by some fishers to be a predator of Snow Crab, and their continued increase in abundance is a source of concern for some fishers and scientists. While seals have been observed with Snow Crab in their stomachs, it should be emphasized that high concentrations of Snow Crab are found in the immediate vicinity of Sable Island, an area where the abundance of Grey Seals is extremely high. There is little evidence suggesting that seals have an overall negative influence on the Snow Crab population. Seal predation of groundfish could also lower potential lateral competition for Snow Crab food resources.

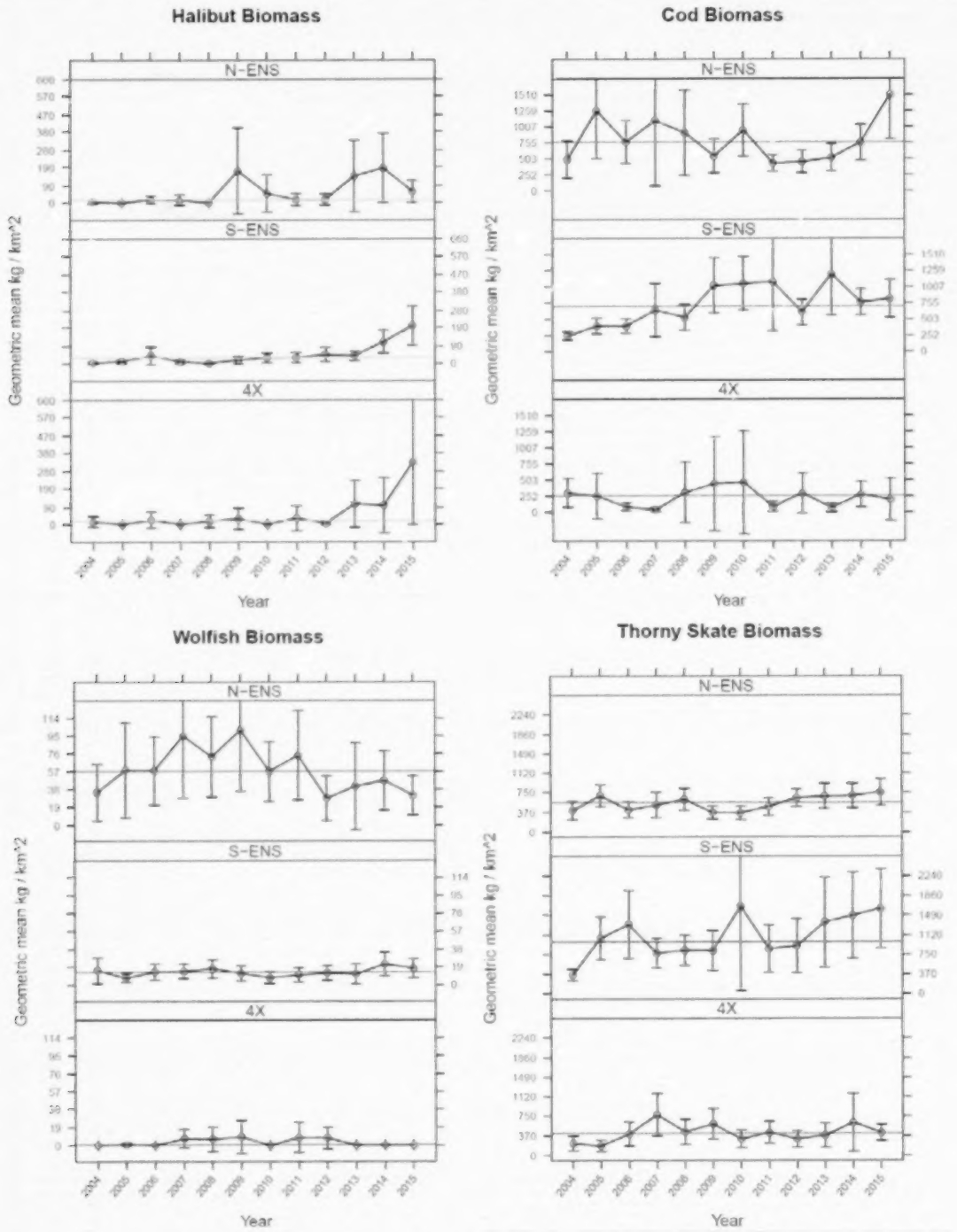

Figure 10. Trends in biomass for potential predators of Snow Crab on the Scotian Shelf, in the Snow Crab Survey.

Fishery Status

Commercial Catch Composition

There has been a shift towards larger animals in N-ENS catches in the past four years, suggesting higher survival of immature crab (lack of handling mortality of soft-shelled crab), while catches in S-ENS have shown a more stable mean crab size (Figure 11). Crab caught in 4X showed an increase in mean size after two consecutive years of decreases.

Carapace condition (CC; Table 2) defines the approximate age (since terminal moult) of the crab based on the relative development and subsequent decay of the carapace. Carapace conditions of commercial catches are subjectively determined by at-sea fisheries observers and can be affected by individual assessment of CC, time of year, etc. Fewer CC2 and more CC3 crab were observed in the catch in 2015, as compared to 2014, in both N-ENS and S-ENS (Figures 12 and 13). 4X catches showed a reduction in CC2 and CC3 with an associated increase in CC4 (Figure 14). No appreciable amount of CC5 crab are observed in any area.

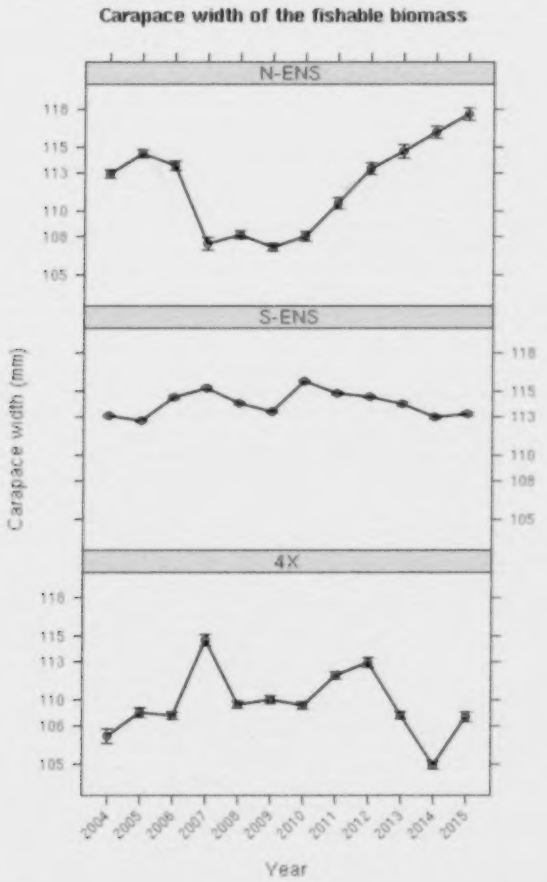

Figure 11. Time series of geometric mean carapace width of commercial crab measured by at-sea-observers. Vertical lines represent 95% confidence intervals. For 4X, the year refers to the end year of the season.

Table 2. Snow Crab carapace conditions (CC) and their description. Hardness is measured by a durometer.

Carapace Condition (CC)	Category	Hardness	Age after Terminal Molt (approx.)
1	New soft	< 68	0 - 5 months
2	Clean	variable	5 months – 1 year
3	Intermediate	> 68	8 months – 3 years
4	Old	> 68	2 - 5 years
5	Very old	variable	4 - 6 years

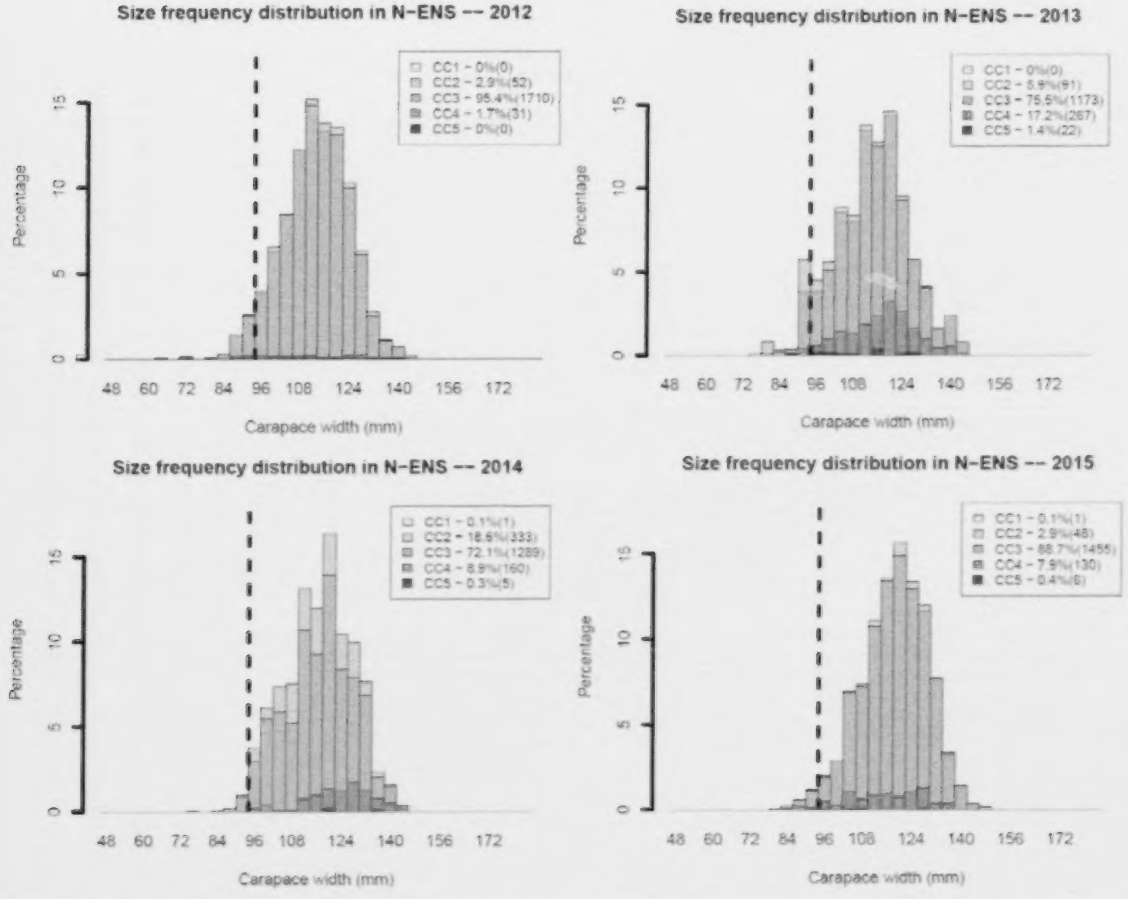

Figure 12. Size frequency distribution of N-ENS at-sea-observer monitored Snow Crab broken down by carapace condition. Vertical lines indicate 95 mm CW.

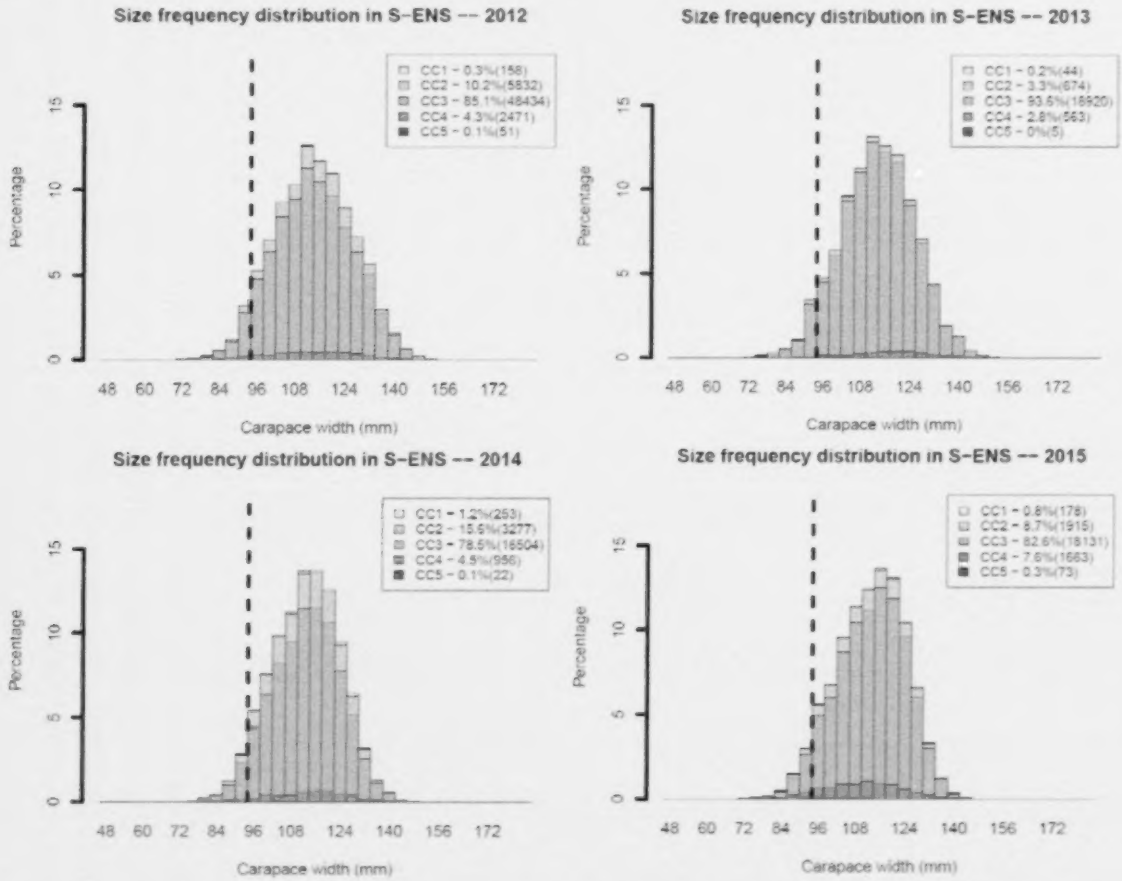

Figure 13. Size frequency distribution of S-ENS at-sea-observer monitored Snow Crab broken down by carapace condition. Vertical lines indicate 95 mm CW.

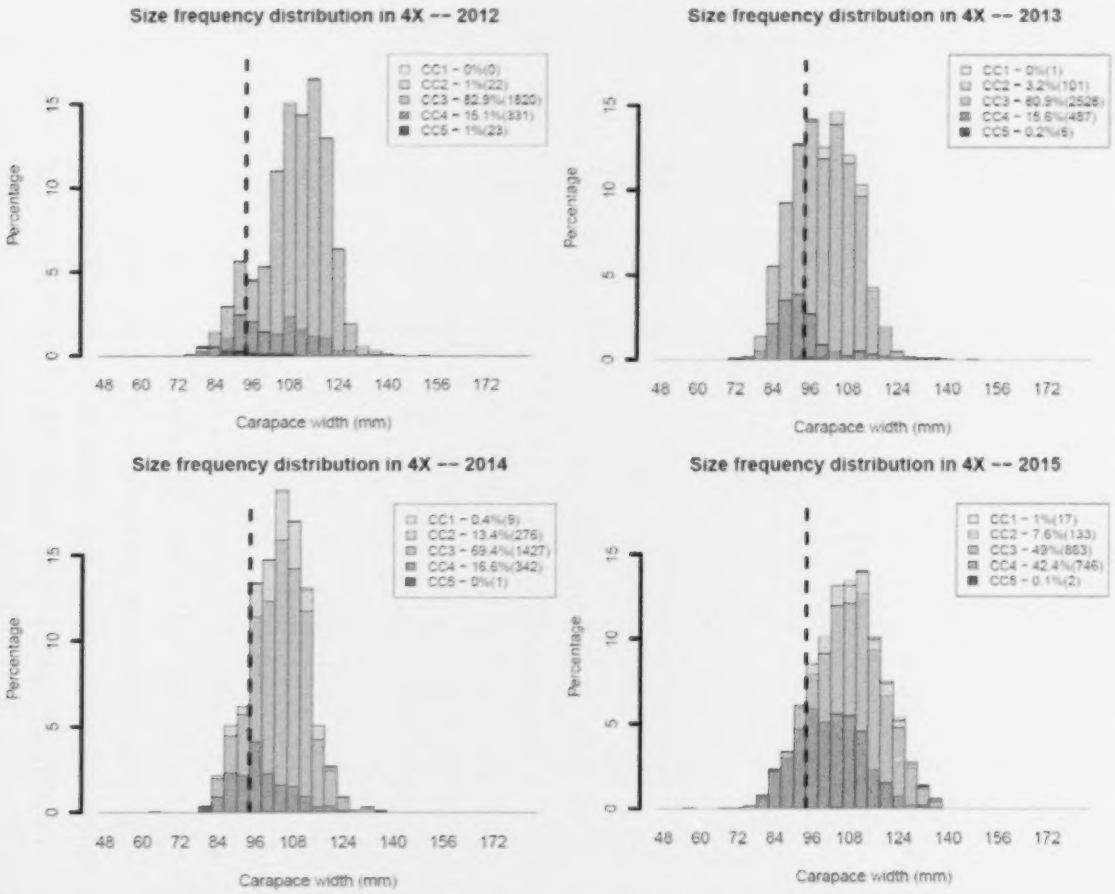

Figure 14. Size frequency distribution of 4X at-sea-observer monitored Snow Crab broken down by carapace condition. Year refers to the starting year of the season. Vertical lines indicate 95 mm CW.

Recruitment

Based on size-frequency histograms of the male Snow Crab population, very limited internal recruitment to the fishery is expected (similar to 2014) in N-ENS and 4X (Figure 15). In N-ENS, a gap persists between 75 and 95 mm carapace width. This gap is expected to maintain depressed recruitment levels for the next 2-7 years, without immigration of crab from adjacent crab fishing areas. However, a pulse of immature crab, first observed at the smallest size classes in 2010, continues to propagate through the system in N-ENS. Each year the gap between this pulse and commercial size decreases, increasing the likelihood of these animals recruiting to the fishery. Area 4X also shows minimal potential for internal recruitment to the fishery. Within 4X, movement of crab from CFA 24 is potentially an important source of crab entering the fishery and a lack of any commercial fishing effort on the western portion of CFA 24 potentially benefits 4X. Immigration of crab from outside a given area can represent recruitment to the fishery but can be unreliable and difficult to estimate, based on its episodic nature. Information obtained through movement studies may help define immigration / emigration patterns.

In S-ENS, internal recruitment is expected to remain at moderate/ consistent levels. The presence of small immature male Snow Crab spanning most size ranges in S-ENS (20-95 mm CW) observed by the survey suggests that recruitment to the fishery is likely for the next 4-5 years.

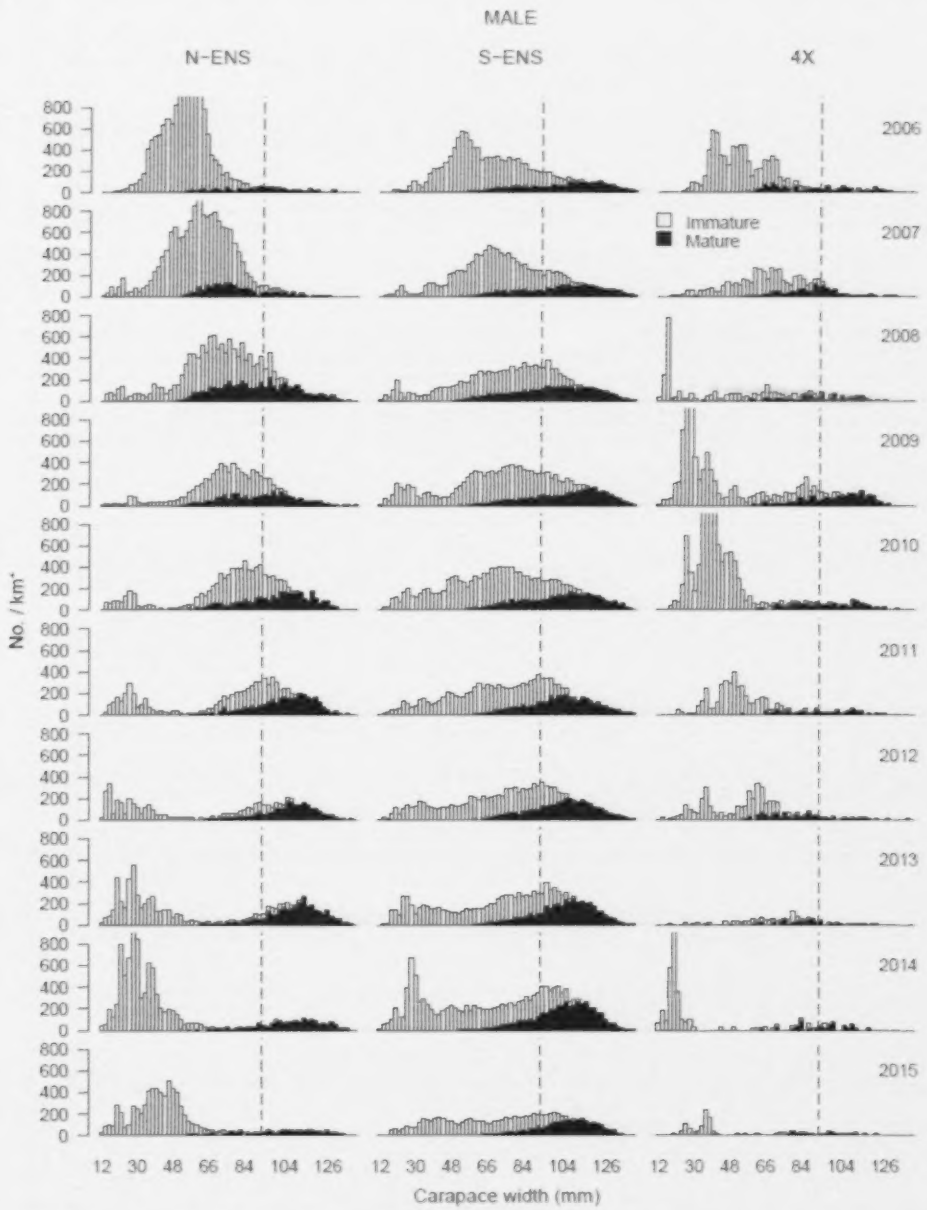

Figure 15. Size-frequency histograms of carapace width of male snow crab. Note the relatively uniform distribution of adolescent crab across all size classes in S-ENS as compared to other areas. For S-ENS and 4X (but not in N-ENS) the spatial extent of the survey has changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year. The vertical line represents the legal size (95 mm).

Reproduction

Sex ratios (proportion female) continued to be male dominated in N-ENS and S-ENS. When the relative number of mature females is high, the possibility of reproductive limitation is present, as there is an absence of large mature males able to mate and protect more rapidly maturing and smaller females. Mature female abundance has increased slightly in N-ENS, likely caused by the earliest maturing animals of a recruitment pulse propagating through the system in all areas since first being observed in 2010. Sex ratios are low, but stable in S-ENS (Figure 16) with geographic pockets of mature females and mature males. In 4X, mature female abundance continues to be at moderate levels, increasing from 2014.

Based on size frequency histograms (Figure 17), newly matured female crab are expected in N-ENS and S-ENS areas for the next 3-4 years. In 4X, newly matured female crab are expected within 2-3 years. Female Snow Crab of a given year-class will mature 2-4 years earlier than a male from the same year-class. As such, male crab from the same cohort are expected to begin maturing in 2-4 years. Each newly matured female should support egg production for 3-5 years.

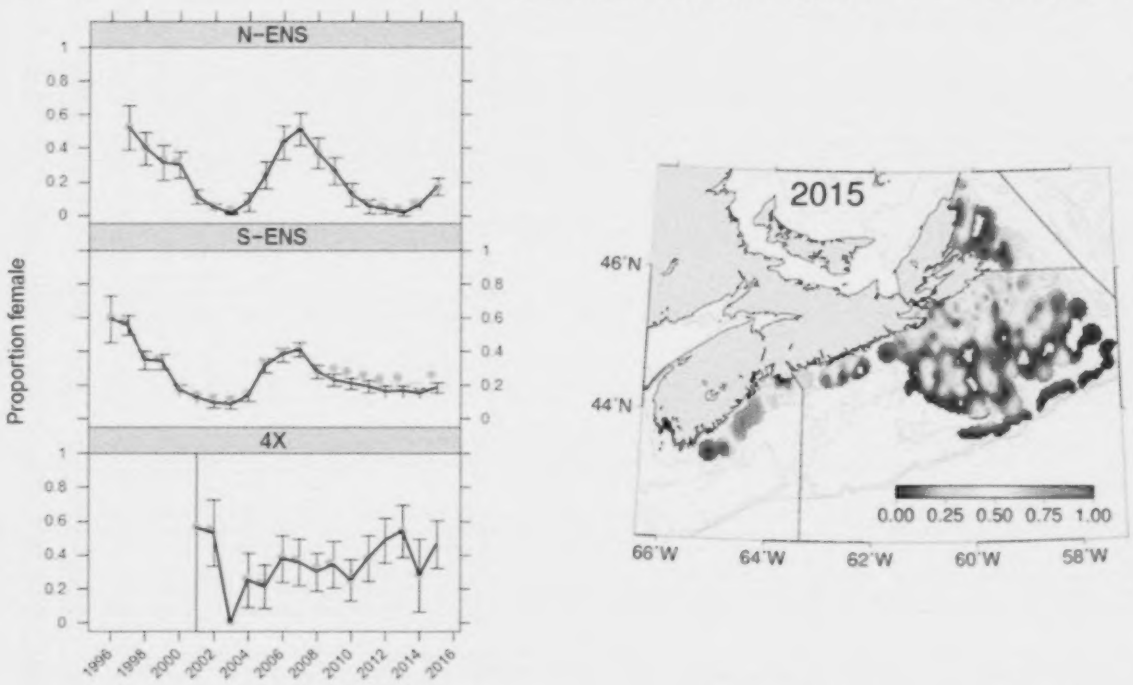

Figure 16. The temporal and spatial of the proportion of mature females to males in the Snow Crab survey data. Note the heterogeneous distribution of sexes in all areas.

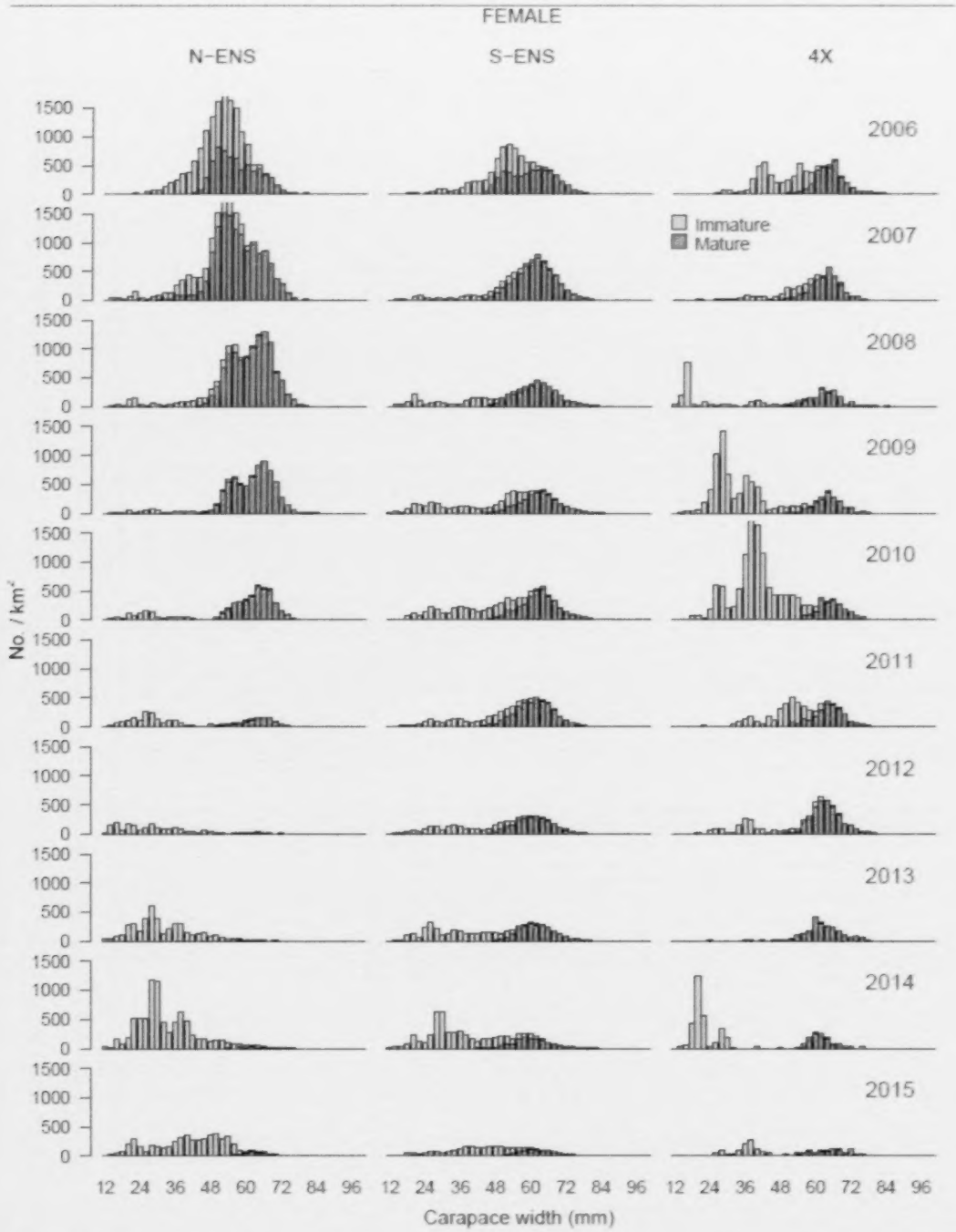

Figure 17. Size-frequency histograms of carapace width of female Snow Crab. Note that for S-ENS and 4X (but not N-ENS) the spatial extent of the survey has changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year.

Fishable Biomass Index

The spatial and temporal distribution of fishable biomass densities are shown in Figures 18-21. Habitat-adjusted fishable biomass estimates[3] were not available at the time of writing of this summary. As such, the fishable biomass index was estimated as the geometric mean abundance scaled by the catchability estimated by the surplus production model. It is anticipated that these estimates will be conservative compared to the habitat-adjusted fishable biomass estimates.

In N-ENS, the post-fishery geometric mean fishable biomass[4] index of Snow Crab in 2015 was 1,429 t, relative to 2,707 t in 2014, representing a 47% decrease (Figure 21). This decreasing trend has been observed for the past four years. The geometric mean fishable biomass is below the long-term average (Figure 19). In N-ENS declines in fishable biomass were evenly spatial distributed (Figure 18). An increased fishable biomass was found in three tows in west of the Glace Bay Hole area (Figures 18 and 20).

In S-ENS, the post-fishery geometric mean fishable biomass index of Snow Crab in 2015 was 40,541 t, relative to 62,162 t in 2014, representing a 35% decrease (Figure 21). The Scotian Slope, and upstream areas of the Gully experienced the largest changes in fishable biomass from 2014 (Figures 18 and 20).

In 4X, the pre-fishery geometric mean fishable biomass index was 651 t, relative to 1,563 t in 2014, representing a 58% decrease (Figure 21). The 2014 biomass estimate in 4X was, however, highly uncertain as only a subset of survey stations in the areas of highest densities were completed in 2014 (Figure 18). A comparison to the 2013 fishable biomass index is more relevant, which was 260 t, representing a 150% increase from 2013. The spatial distribution of fishable biomass in 4X was patchy, with little or no change in fishable biomass in the majority of tows that surveyed in both 2014 and 2015 (Figure 18).

[3] The fishable biomass, expanded to the area where the probability of occurrence of fishable crab is greater than 0.05.
[4] The geometric mean biomass, per area, based on tows conducted during the annual Snow Crab survey

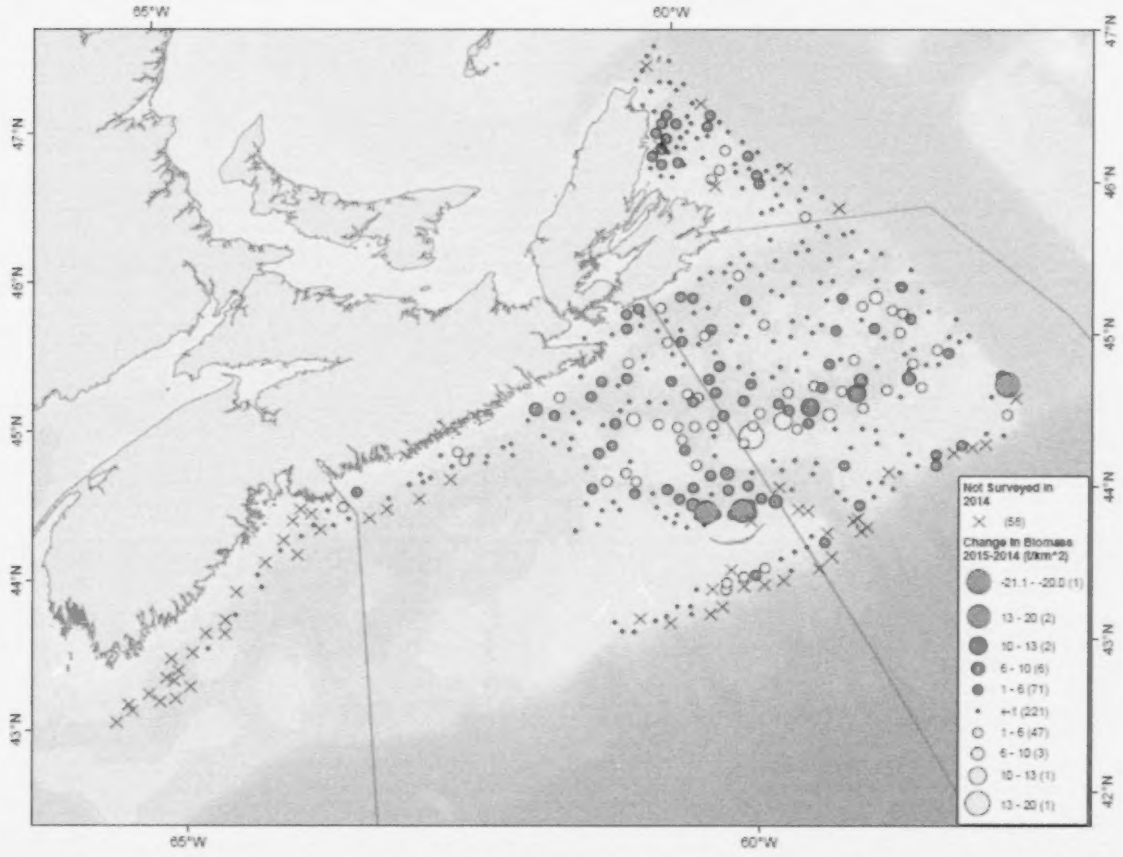

Figure 18. Change in fishable biomass (t\km^2) from 2014 to 2015 (2015-2014) in the Snow Crab survey. Red dots indicate a decrease in biomass found at that location in 2015, while green dots indicate an increase. An X on the map indicates a station that was not surveyed in 2014, but surveyed in 2015. Only a subset of survey stations were completed in 2014

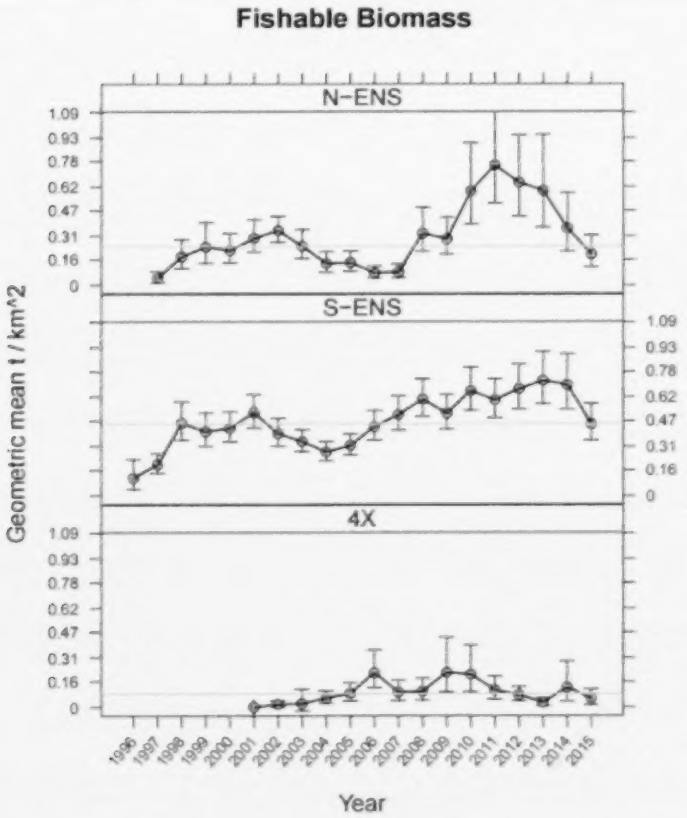

Figure 19. Temporal trends in the geometric mean fishable biomass (t/km^2) found in the Snow Crab survey.

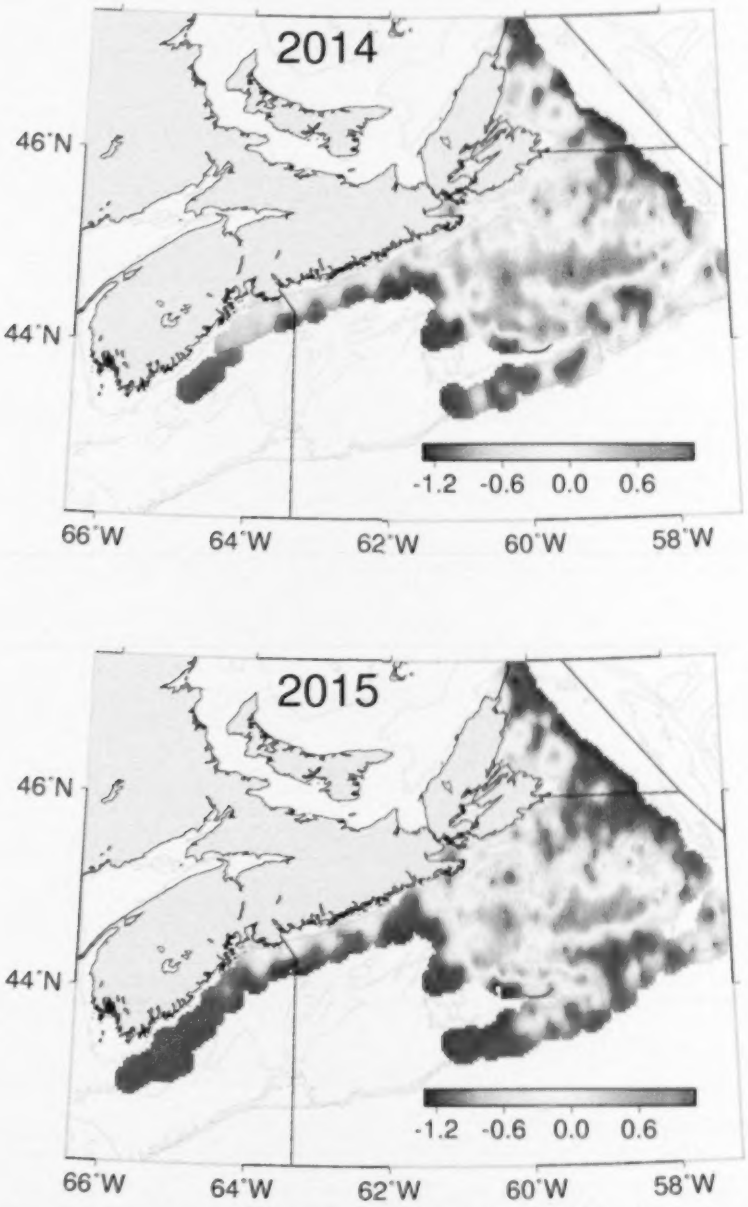

Figure 20. Interpolated fishable biomass from the 2014 and 2015 Snow Crab survey. Log10 kg\km^2.

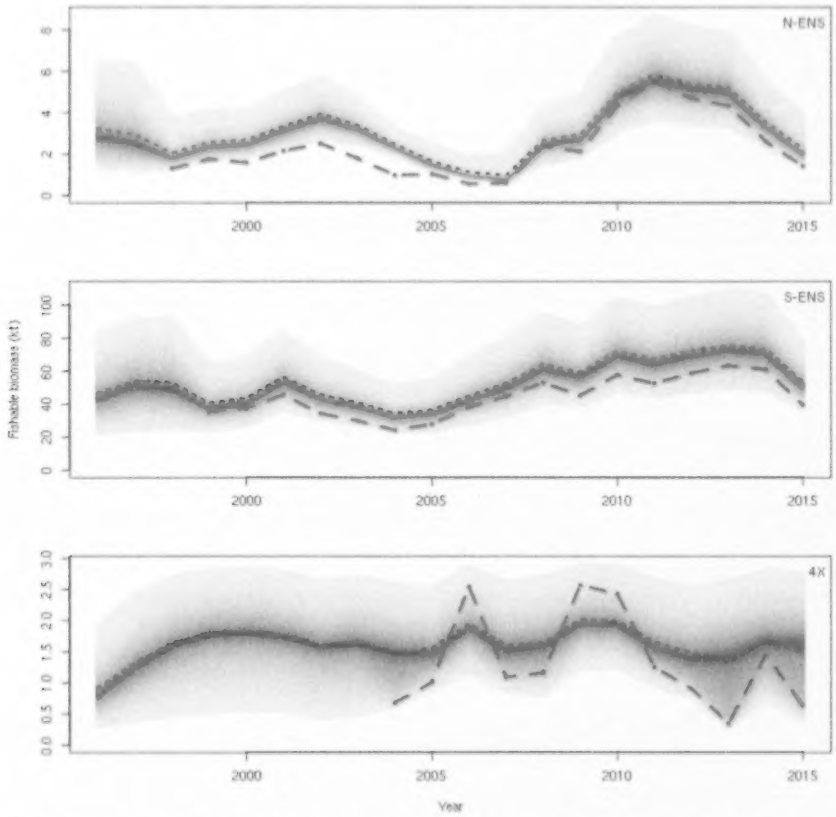

Figure 21. Time series of fishable biomass from the logistic population models. The scaled geometric mean fishable biomass index is shown as a green line. The posterior mean fishable biomass, estimated from the logistic population model, is shown as a blue dashed line. The density distribution of posterior fishable biomass estimates are presented (grey) with the darkest area being medians and the 95% Credible Intervals (CI).

Precautionary Approach

In N-ENS the modeled fishable biomass[5] has decreased over the past four years, and placed the stock into the "cautious" zone (LSR < FB < USR; Figure 22).

In S-ENS the population is considered to be in the "healthy" zone (FB > USR; Figure 22).

In 4X, despite a large modeled fishable biomass decrease this year, the population is still considered to be in the "healthy" zone (FB > USR; Figure 23). However, direct comparison of 2014 and 2015 results is difficult due to reduced survey coverage in 2014 in 4X. There was little or no change in fishable biomass in the majority of tows that were surveyed in both 2014 and 2015.

[5] The fishable biomass estimated by the surplus production fishery model.

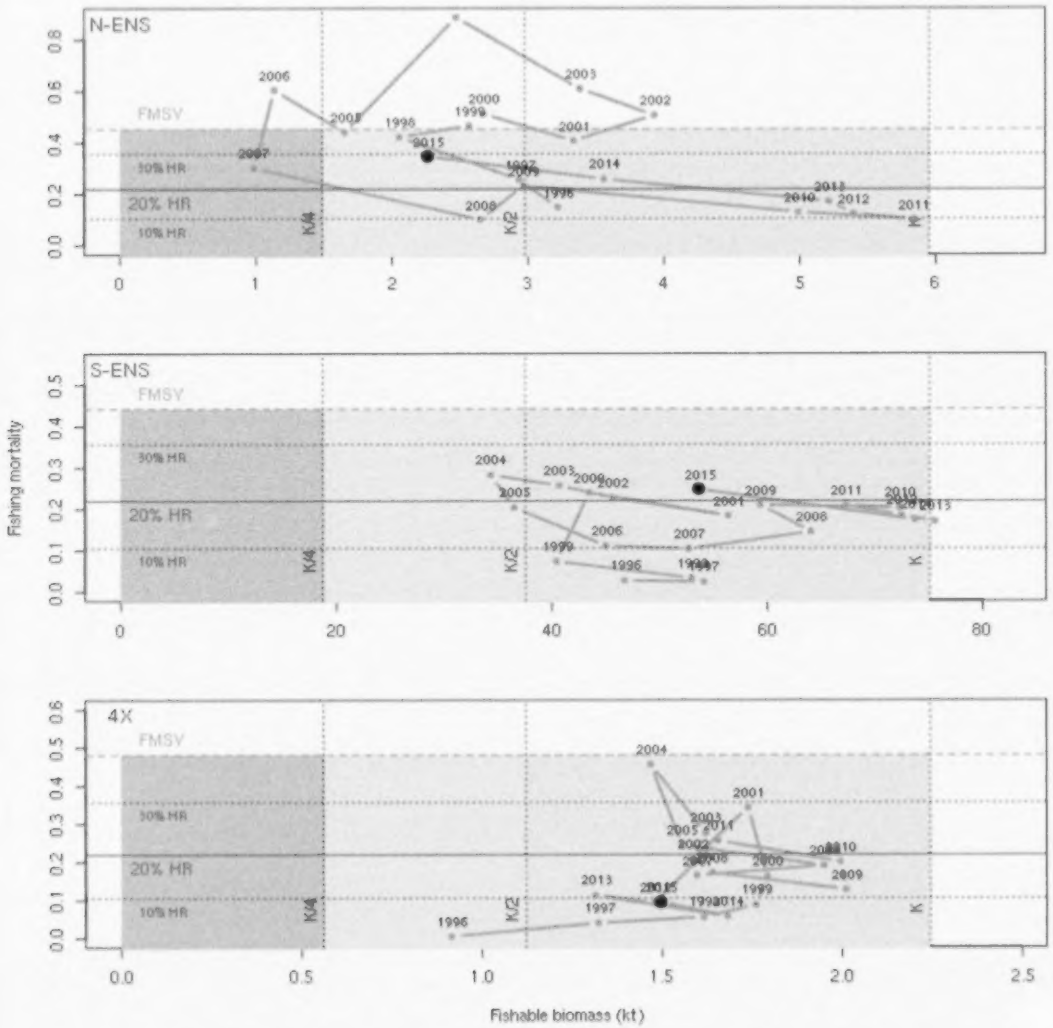

Figure 22. Time series of fishing mortality and fishable biomass for N-ENS (top), S-ENS(middle), and 4X(bottom) obtained from the logistic population models, overlaid onto the Harvest Control Rules for this fishery.

Fishing Mortality

In N-ENS, modeled Fishing Mortality (F) has been estimated to have been in the range of 0.1 to 0.9, peaking in 2004 (Figure 23). In 2015, fishing mortality is estimated to have been 0.35 and has been increasing over the past several years. A reduction in fishing mortality in 2008 was implemented to reduce soft shell handling.

Modeled fishing mortality for S-ENS has historically ranged from 0.05 to 0.25, peaking in 2003/2004 (Figure 22). In 2015, fishing mortality was estimated to have been 0.24, the highest since the early 2000's. Localized exploitation rates are likely higher, as not all areas where biomass estimates are provided are fished (e.g. continental slope areas and western, inshore areas of CFA 24).

In 4X, modeled fishing mortality has historically ranged from 0.2 to > 0.4, peaking in 2005 and 2011/2012 (Figure 22). In 2014/2015, estimated fishing mortality was 0.042. Realized exploitation rates are anticipated to be higher, since the computed exploitation rates incorporate biomass throughout the 4X area and not just the fishery grounds.

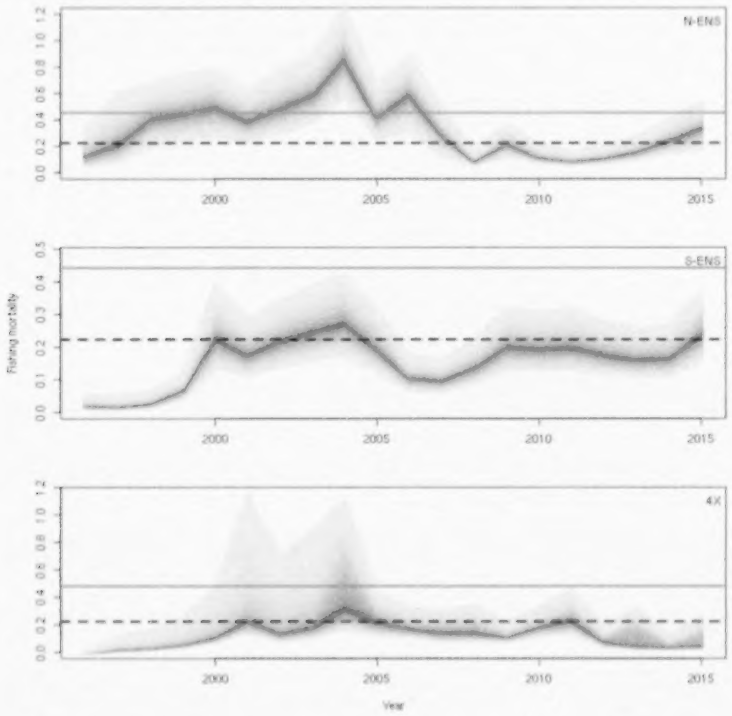

Figure 23. Time series of fishing mortality from the logistic population models for N-ENS, S-ENS and 4X. Posterior density distributions are presented in gray, with the darkest line being the median with 90% CI. The red line is the estimated FMSY (F at Maximum Sustainable Yield) and the dark-dashed line is the 20% harvest rate.

Carrying Capacity

From the logistic model output, the current estimates of carrying capacity for the fishable biomass of Snow Crab are estimated to be (and 95% CI):

- N-ENS: 5.81 (4.16, 8.54) kt
- S-ENS: 73.5 (53.7, 105) kt
- 4X: 2.21 (1.65, 2.99) kt

FMSY

The estimates of FMSY (and 95% CI) were:

- N-ENS: 0.453 (0.357, 0.549)
- S-ENS: 0.442 (0.345, 0.543)
- 4X: 0.481 (0.381, 0.579)

Estimates for 4X should be considered highly uncertain, due to the brevity of their data series and uncertain nature of their distributions.

Conclusions

Habitat-adjusted fishable biomass estimates were not available for this assessment. As such, the fishable biomass index was estimated as the geometric mean abundance scaled by the catchability estimated by the surplus production model. It is expected that these estimates will be conservative compared to the habitat-adjusted fishable biomass estimates.

N-ENS

In N-ENS the geometric mean fishable biomass has decreased over the past four years, and placed the stock into the "cautious" zone. In 2015, geometric mean fishable biomass decreased by 47%. Fishing mortality in 2015 was estimated at 35%, and has also been increasing over the past few years, due to lack of recruitment into the fishery. Depressed recruitment into the fishery is expected for the next 3-7 years, without immigration of crab from adjacent fishing areas. Recruitment is expected to recover in the long-term; newly mature female Snow Crab are expected in N-ENS for the next 3-4 years, and sex ratios are recovering from near zero. Movement is potentially an important source of crab in this area, but is unreliable and difficult to estimate, based on its episodic nature. Based on the biomass trends obtained during the survey and recruitment patterns, until a strong and persistent increase in fishable biomass is observed, the harvest control rules for the "cautious" zone are to maintain harvest rates between 0% and 20%. A decreased TAC is recommended.

S-ENS

In S-ENS the population is considered to be in the "healthy" zone. There was, however, a large decrease in geometric mean fishable biomass (35%). This decrease was likely over two years, due to a slightly inflated geometric mean biomass estimate in 2014. Fishable biomass appeared to be retracted to primary habitat due to warmer temperatures surrounding primary Snow Crab habitat. Similarly, the spatial distribution of higher landings and catch rates decreased. Increasing temperatures are expected to have long-term effects decreasing the available Snow Crab habitat.

Despite long-term habitat concerns, the population is still high compared to historic levels and recruitment into the fishery is stable. Fishing mortality is currently slightly above the 20% exploitation rate (23%) and at the highest level since the early 2000's. Biomass of predators has been increasing over time, and potentially has long-term effects on biomass. Harvest control rules for the cautious zone are to maintain harvest rates between 10% and 30%. A decrease in TAC is recommended to maintain the 20% exploitation rate.

4X

Area 4X is the southern-most area of Snow Crab distribution, existing in more "marginal" environments relative to the "prime" areas of S- and N-ENS. An explicitly PA towards the fishery is essential in this area. Further, the lower recruitment into the fishable biomass and the large inter-annual temperature variations (especially in 2012) increases the uncertainty associated with this area. In the past, S-ENS has been assumed to provide a buffer for 4X via immigration as evidenced by a large portion of 4X's commercial biomass being proximal to the S-ENS line. Direct comparison of 2014 and 2015 results are difficult due to a much reduced survey in 2014 in 4X. However, there was little or no change in fishable biomass in the majority of tows that

were surveyed in both 2014 and 2015. Recruitment patterns show minimal recruitment is expected into the fishery over the next 2-3 years. Based on the fishable biomass of survey stations surveyed in both 2014 and 2015, and expected recruitment, a decrease in TAC is recommended pending further analysis prior to the 2015/2016 season.

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